

**Model Answers: Hard**

1

The correct answer is **B** as:

- **HCO<sup>3-</sup> ions** (also known as bicarbonate) are transported in the **blood plasma**
- **carbonic anhydrase** is an enzyme found in **erythrocytes** (red blood cells)
- **lysosomes** are found in the cytoplasm of **macrophages** (phagocytotic white blood cells)

**1 = alveolar wall (a squamous epithelial cell - the small circle is the nucleus)**

**2 = capillary wall (a squamous epithelial cell)**

**3 = erythrocyte (red blood cell)**

**4 = lumen of an alveoli**

**5 = the lumen of a capillary**

**6 = the cytoplasm of a macrophage (phagocytotic white blood cell)**

Carbon dioxide can be transported through the blood one of via three methods: dissolved directly in the blood, bound to haemoglobin or converted into **HCO<sup>3-</sup> ions** (aka bicarbonate). The majority of carbon dioxide is transported via the bicarbonate system. Carbon dioxide diffuses into red blood cells, where **carbonic anhydrase** converts it into **carbonic acid** (H<sub>2</sub>CO<sub>3</sub>). This is subsequently hydrolysed into **bicarbonate** (HCO<sup>3-</sup>) and **H<sup>+</sup>**. The **H<sup>+</sup>** ion binds to haemoglobin in red blood cells, and bicarbonate is transported out of the red blood cells in exchange for a chloride ion (this is called the **chloride shift**). **Bicarbonate** leaves the red blood cells and enters the blood plasma. In the lungs, bicarbonate is transported back into the red blood cells in exchange for chloride. The **H<sup>+</sup>** dissociates from haemoglobin and combines with bicarbonate to first form carbonic acid, then, eventually (with the help of **carbonic anhydrase**) carbon dioxide (which is then expelled from the lungs).

**Lysosomes** are found in most cells but are particularly plentiful in **macrophages** (as these cells engulf and destroy pathogens). Lysosomes are small vesicles of **hydrolytic enzymes**. Once a macrophage engulfs a pathogen (via phagocytosis) the bacteria ends up in a membranous sac called a **phagosome**. When a phagosome encounters a lysosome inside the cell, the

two membranes fuse creating a **phagolysosome** (which is where the bacteria get digested).

2

The correct answer is **C** as:

- The question is asking about the sequence of events in **exocytosis** (i.e. the process of moving materials from within a cell to the exterior of the cell).
- The main role of goblet cells is to secrete mucus in order to protect the mucous membranes where they are found.
- The mucus the goblet cells secrete is comprised of large glycoproteins.
- The first step to create these **glycoproteins** is by attaching carbohydrate to a protein (**2**).
- The next step is to create the vesicle, and this is done in the **Golgi apparatus** (**3**).
- The vesicles (containing the newly synthesised mucus) are then transported from the Golgi to the cell membrane.
- The vesicle membrane attaches to the cell membrane (**4**).
- Fusion of the vesicle membrane with the cell membrane releases the vesicle contents (glycoprotein) outside the cell (**1**).

3

The correct answer is **C** as tissue **X** is **cartilage**. The **bronchus** is a wide flexible tube, the lumen of which is kept open by **plates of cartilage**. The cartilage prevents the collapse of the bronchus during **inhalation** (when there is a low pressure).

**A + B** would be referring to smooth muscle and **D** would be referring to goblet cells.

4

The correct answer is **B** as during the course of the four minutes they inhaled and exhaled **36 dm<sup>3</sup>** of air.

To calculate the total amount of air breathed in four minutes first times the tidal volume by the breathing rate (to get the **breathing rate for one minute**)

$$0.6 \times 15 = 9 \text{ dm}^3 \text{ min}^{-1}$$

Then multiply by 4 (to get the **rate for four minutes**)

$$9 \times 4 = 36 \text{ dm}^3$$

5

The correct answer is **B** as:

- Increased **exocytosis** causes a faster rate of mucus production
- Contraction of the smooth muscle is responsible for the narrowing of the airways
- During an asthma attack the rate of respiration in the smooth muscle will be higher as **energy is needed for muscle contraction**
- Despite the increased mucus production, there is no change in the activity of the ciliated epithelial cells (hence **2** not being a response)
- The build-up of mucus further contributes to the difficulty of breathing caused by the narrowing of the airways

The main role of goblet cells is to secrete mucus in order to protect the mucous membranes where they are found. Goblet cells accomplish this by secreting large glycoproteins. The first step is to create these **glycoproteins** by attaching carbohydrate to a protein. The next step is to create the vesicle, and this is done in the **Golgi apparatus**. The vesicles (containing mucus) are then transported from the Golgi to the cell membrane. The vesicle membrane then attaches to the cell membrane. Finally, fusion of the vesicle membrane with the cell membrane releases the vesicle contents (glycoprotein) outside the cell.

6

The correct answer is **C** as:

- Goblet cells need large numbers of **secretory vesicles** for transporting synthesised mucus out of the cell (**exocytosis**)
- Mucus is a type of **glycoprotein** and lots of **rough endoplasmic reticulum** is needed to create the **protein** part of this glycoprotein
- Both exocytosis and protein synthesis are active processes requiring large amounts of **ATP**, therefore there is an abundance to **mitochondria** (to synthesise ATP)

The **rough endoplasmic reticulum** is a series of connected flattened sacs that plays a central role in the synthesis of proteins. The rough endoplasmic reticulum is so named for the appearance of its outer surface, which is studded with **protein-synthesizing** particles known as **ribosomes**. This feature distinguishes it superficially and functionally from the other major type of endoplasmic reticulum - the **smooth endoplasmic reticulum**. Smooth endoplasmic reticulum lacks ribosomes and is involved in the synthesis and storage of **lipids**.

7

The correct answer is **B** as the overall volume of the lungs is not affected, however the damage to the walls would lead to a **reduced** surface area. One such disease that could damage the lungs in this way is emphysema.

**Emphysema** is a lung condition that causes shortness of breath. In people with emphysema the alveoli are damaged. Over time, the inner walls of the

alveoli weaken and rupture, creating larger air spaces instead of many small ones. This reduces the **surface area** of the lungs and, in turn, the amount of **oxygen** that reaches the **bloodstream**.

8

The correct answer is **C** as:

- The additional **mucus production** leads to **mucus build up**. If this mucus not cleared it can harbor pathogens, therefore, leading to an increased risk of lung infection – so **2** is correct
- The **diffusion gradient** is also **decreased** as the airflow into and out of the lungs is restricted (both by the narrowing of the lumen and the buildup of mucus). This decrease in airflow results in the air spending longer than usual in the alveoli, leading to a buildup of carbon dioxide and a reduction in oxygen concentration of the air in the alveoli. The concentrations of these gases in the alveoli are now more similar to the concentrations found in the blood, therefore diffusion of gases between the blood and alveoli will be slower (due to the **reduced concentration gradient**) - so **3** is correct
- There is no change to the diffusion distance as the structure of the alveolar and capillary walls are unchanged - so **1** is incorrect

Allergy-induced asthma is triggered by airborne substances, such as pollen, mould spores, dust mites or particles of skin and fur shed by pets.

9

The correct answer is **A** as there is no evidence to suggest lung cancer takes 20 years to develop. The deaths per 100,000 of age group does rise for a 20-year period (from 1950 – 1970), however this does not imply that cancer takes 20 years to develop. We would require more information (such as cause of death and the years the individual had or hasn't smoked) to be able to ascertain whether this statement is indeed true.

**B** is incorrect as deaths per 100,000 in men 35-59 has fallen from ~50 to ~25 over the period of the study, so the statement is true

**C** is incorrect as the number of men aged 35-59 who were smokers has gone from around 82% to 36%  $(36 / 82) - 1 = -0.56$

this is a 56% decrease (approximately 60%) and therefore the statement is true

**D** is incorrect as as the number of deaths rose continually between 1950 and 1970 so the statement is true

10

The correct answer is **A**. Macrophages (a type of **phagocyte**) invade the walls of the **alveoli** and release **elastase**, which breaks down the elastic fibres

in the alveoli. Without elastic fibres there is no **elastic recoil** (hence why the alveoli are unable to return to their original shape after inhalation).